CLAIMS

What is claimed is:

1. A method for controlling distribution of refrigerant among a plurality of refrigerators comprising:

determining an available quantity of the refrigerant;

determining a demand of the refrigerant by each of the plurality of refrigerators;

aggregating the demand from the refrigerators;

determining, for each of the refrigerators, an allocation of the refrigerant based on the availability of the refrigerant, the aggregated demand and the individual needs of the refrigerators; and

redistributing the allocation of the refrigerant over time by redetermining the allocation of the refrigerant.

2. The method of claim 1 further comprising recomputing the available quantity of the refrigerant, wherein the redistributing further comprises redistributing based on the recomputed available quantity of the refrigerant.

3. The method of claim 1 wherein the computing and recomputing the available quantity of the refrigerant further comprises computing in a master controller in communication with each of the refrigerators.

4. The method of claim 1 wherein the refrigerator further comprises a slave controller operable to control consumption of the refrigerant by the refrigerator and the computing and recomputing the demand further comprises computing in the slave controller.

5. The method of claim 1 further comprising determining a master controller state indicative of demand for and availability of the refrigerant, wherein redistributing the allocation of the refrigerant includes computing based on the master controller state.

6. The method of claim 1 further comprising determining a refrigerator status and mode indicative of a refrigerant demand of the refrigerator, wherein redistributing the allocation of the refrigerant includes computing based on the refrigerator status and mode.

7. The method of claim 1 wherein computing and recomputing in the master and slave controllers occurs according to a predetermined set of rules and thresholds.

8. The method of claim 1 wherein computing and recomputing the demand further comprising sensing at least one operating parameter of the refrigerator.

9. The method of claim 8 wherein the operating parameters include parameters selected from the group consisting of temperature, supply pressure, return pressure, speed, and allocated helium.

10. The method of claim 1 wherein the demand is indicative of a rate of helium consumption over time.

11. The method of claim 1 wherein computing the allocation further comprises sensing at least one operating parameter of the refrigerator.

12. The method of claim 11 wherein the at least on operating parameter is a differential pressure (DP).

13. The method of claim 1 wherein the refrigerators have variable rates of consumption

14. The method of claim 1 wherein the allocation of the refrigerant further comprises a maximum consumption rate.

15. The method of claim 5 further comprising evaluating the demand for and availability of the refrigerant, and determining the master controller state as a result of the evaluation.

16. The method of claim 15 wherein a monitor state is indicative of a sufficient allocation of the refrigerant to all of the refrigerators.

17. The method of claim 15 wherein a distribution per demand state is indicative of at least one refrigerator having an insufficient allocation of the refrigerant.

18. The method of claim 15 wherein an overload state is indicative of at least one of the refrigerators having an insufficient allocation of the refrigerant and an aggregate demand has reached the available supply.

19. The method of claim 15 wherein a distribution per hierarchy state is indicative of selectively diverting the refrigerant away from refrigerators according to a predetermined order.

20. The method of claim 1 wherein redistributing further comprises incrementally increasing control parameters according to the predetermined rules.

21. The method of claim 1 wherein the computing the available quantity of the refrigerant further comprises computing based on a point of equilibrium between the quantity of the refrigerant and the aggregate demand.

22. The method of claim 1 wherein the refrigerators are included in cryopumps.

23. The method of claim 22 wherein each of the cryopumps has a first stage and a second stage, and computing the demand further comprises reading the temperature of the first stage and the second stage and computing in response to the temperature.

24. The method of claim 1 wherein the system is a fluid supply system.

25. The method of claim 1 wherein the refrigerant is helium.

26. The method of claim 1 wherein the refrigerant is distributed from a common manifold.

27. The method of claim 1 wherein the computing and recomputing the available quantity of the refrigerant further comprises computing in a master controller in communication with each of the refrigerators.

28. The method of claim 4 wherein the slave controller is a cryopump controller.

29. A system for controlling distribution of a refrigerant among a plurality of refrigerators comprising:

a plurality of refrigerators adapted to consume a refrigerant;

a plurality of slave controllers each controlling consumption of a refrigerant by a refrigerator, the slave controller operable to compute a demand of the refrigerant by the refrigerator;

a master controller in communication with each of the slave controllers, the master controller operable to compute an available quantity of the refrigerant, and further operable to receive a demand from each of the

refrigerators and compute an allocation of the refrigerant to each of the refrigerators based on an aggregated demand.

30. The system of claim 29 wherein the master controller is operable to recompute the available quantity of the refrigerant and further operable to recompute the allocation of the refrigerant based on the recomputed available quantity of the refrigerant.

31. The system of claim 30 further comprising a master controller state indicative of demand for and availability of the refrigerant, wherein computing and recomputing the allocation of the refrigerant includes computing based on the master controller state.

32. The system of claim 30 further comprising a refrigerator status and mode indicative of refrigerant demand of the refrigerant, wherein computing and recomputing the allocation of the refrigerant includes computing based on the refrigerator status and mode.

33. The system of claim 30 wherein computing and recomputing in the master and slave controllers occurs according to a predetermined set of rules and thresholds.

34. The system of claim 29 wherein the slave controllers are further operable to compute the demand of the refrigerant by the refrigerant based on at least one operating parameter of the refrigerator.

35. The system of claim 34 wherein the operating parameters include parameters selected from the group consisting of temperature, supply pressure, return pressure, speed, and allocated helium.

36. The system of claim 29 wherein the demand is indicative of a rate of helium consumption over time.

37. The system of claim 30 wherein the master controller is further operable to compute and recompute the allocation based on at least one operating parameter of the refrigerator.

38. The system of claim 37 wherein the at least on operating parameter is a differential pressure (DP).

39. The system of claim 29 wherein the refrigerators have variable rates of consumption

40. The system of claim 29 wherein the allocation further comprises a maximum consumption rate.

41. The system of claim 31 wherein a monitor state is indicative of a sufficient allocation of the refrigerant to all of the refrigerators.

42. The system of claim 31 wherein a distribution per demand state is indicative of at least one refrigerant having an insufficient allocation of the refrigerant.

43. The system of claim 31 wherein an overload state is indicative of at least one of the refrigerators having an insufficient allocation of the refrigerant.

44. The system of claim 31 wherein a distribution per hierarchy state is indicative of selectively diverting the refrigerant away from refrigerators according to a predetermined order.

45. The system of claim 31 wherein the master controller is further operable to compute the master controller state based on a setpoint, the setpoint corresponding to equilibrium between the quantity of the refrigerant and the aggregate demand.

46. The system of claim 29 wherein the refrigerators are included in cryopumps.

47. The system of claim 46 wherein each of the cryopumps has a first stage and a second stage, and computing the demand further comprises reading the temperature of the first stage and the second stage and computing in response to the temperature.

48. The system of claim 29 wherein the system is a fluid supply system.

49. The system of claim 29 wherein the refrigerant is helium.

50. The system of claim 29 wherein the refrigerant is distributed from a common manifold.

51. The method of claim 1 wherein the computing and recomputing the available quantity of the refrigerant further comprises computing in a master controller in communication with each of the compressors

52. The system of claim 29 wherein the slave controller is a cryopump controller.

53. A computer program product having computer program code for controlling distribution of refrigerant among a plurality of refrigerators comprising:

computer program code for determining an available quantity of the refrigerant;

computer program code for determining a demand of the refrigerant by each of the plurality of refrigerators;

computer program code for aggregating the demand from the refrigerators;

computer program code for determining, for each of the refrigerators, an allocation of the refrigerant based on the availability of the refrigerant, the aggregated demand and the individual needs of the refrigerators; and

computer program code for redistributing the allocation of the refrigerant over time by redetermining the allocation of the refrigerant.

54. A computer data signal including program code for controlling distribution of refrigerant among a plurality of refrigerators comprising:

program code for determining an available quantity of the refrigerant;

program code for determining a demand of the refrigerant by each of the plurality of refrigerators;

program code for aggregating the demand from the refrigerators;

program code for determining, for each of the refrigerators, an allocation of the refrigerant based on the availability of the refrigerant, the aggregated demand and the individual needs of the refrigerators; and

program code for redistributing the allocation of the refrigerant over time by redetermining the allocation of the refrigerant.

55. A system for controlling distribution of a refrigerant among a plurality of refrigerators comprising:

means for determining an available quantity of the refrigerant;

means for determining a demand of the refrigerant by each of the plurality of refrigerators;

means for aggregating the demand from the refrigerators;

means for determining, for each of the refrigerators, an allocation of the

refrigerant based on the availability of the refrigerant, the aggregated demand and the individual needs of the refrigerators; and

means for redistributing the allocation of the refrigerant over time by redetermining the allocation of the refrigerant.

56. A method of delivering helium to a plurality of cryogenic refrigerators connected to a common refrigerant source comprising:

sensing at least one operating parameter indicative of the operating status of each cryogenic refrigerator;

computing, at a controller, from the at least one parameter and a helium supply, an allocation signal indicative of an allocation of refrigerant, the allocation signal computed in response to a computed helium consumption; and

controlling a drive motor connected to each of the cryogenic refrigerators to regulate the helium consumed by the cryogenic refrigerator according to the allocation signal.

57. The method of claim 56 wherein the sensing, computing, and controlling recurs at regular, predetermined intervals according to a control loop.

58. The method of claim 56 wherein the allocation signal corresponds to units of mass flow rate.

59. The method of claim 56 wherein the common refrigerant source is a helium supply driven by a compressor.

60. The method of claim 56 wherein the cryogenic refrigerator is in a cryogenic pump.

61. The method of claim 56 wherein computing the allocation signal further comprises computing based on the temperature of the refrigerant, the computed mass flow rate of the refrigerant, the pressure and temperature of the refrigerant, and the speed of the motor.

62. The method of claim 56 wherein each of the cryogenic refrigerators is operable to perform a plurality of cryogenic functions and the allocation signal is computed based on the cryogenic function and operating parameters.

63. The method of claim 57 wherein the control loop is a closed feedback loop.

64. The method of claim 56 wherein the at least one operating parameter corresponds to the operating parameters selected from the group consisting of temperature, supply pressure of the refrigerant, return pressure of the refrigerant, pump speed, and allocated helium.

65. A helium management control system for a plurality of cryogenic refrigerators comprising:

a plurality of cryogenic refrigerators connected to a common refrigerant source, each of the cryogenic refrigerators operable to cool a refrigerant load;

a drive motor connected to each of the cryogenic refrigerators and operable to regulate the helium consumed by the cryogenic refrigerators;

at least one sensor in communication with each of the cryogenic refrigerators adapted to sense at least one operating parameter indicative of the operating state of the cryogenic refrigerators;

a controller operable to receive the operating parameters and compute an aggregate refrigerant load indicative of a plurality of the refrigerant loads, the controller further operable to compute an allocation signal as a result of the aggregate refrigerant load; and

a drive motor controller connected to each of the sensors and to each of the drive motors, the controller operable to regulate the drive motor in response to the allocation signals.

66. The system of claim 65 further including a refrigerant capacity indicative of a cooling potential of the common refrigerant source, the controller further operable to compute the allocation signal as a result of the refrigerant capacity.

67. The system of claim 66 wherein the refrigerant capacity is a computed available helium supply driven by a compressor.

68. The system of claim 65 wherein the cryogenic refrigerator is in a cryogenic pump.

69. The system of claim 65 wherein the controller is further operable to compute the allocation signal based on the temperature of the refrigerant, the computed flow rate of the refrigerant, the pressure of the refrigerant, and the speed of the motor.

70. The system of claim 65 wherein each of the cryogenic refrigerators is operable to perform a plurality of cryogenic functions and the drive signal is computed based on the cryogenic function.

71. The system of claim 65 wherein the controller is operable to recompute the consumption signal at regular, predetermined intervals.

72. The system of claim 69 further including a control loop in the controller operable to compute the allocation signal as a result of the parameters.

73. The system of claim 72 wherein the control loop is a closed feedback loop.

74. The system of claim 65 wherein the at least one sensor includes a temperature sensor.

75. The system of claim 65 wherein the at least one sensor includes a pressure sensor.

76. A method of controlling a system including:

a compressor bank including at least one compressor;

a plurality of cryogenic refrigerators supplied with refrigerant from the compressor bank, the method comprising:

identifying the refrigeration requirements of each of the refrigerators, and

from a controller, allocating a supply of refrigerant to the refrigerators according to the identified requirements.

77. The method of claim 76 wherein identifying the requirements further comprises identifying the consumption of each of the cryogenic refrigerators.

78. The method of claim 77 wherein allocating further comprises allocating by controlling the speed of the drive motor as a result of a temperature threshold.

79. The system of claim 29 wherein the refrigerator is included in a waterpump.

80. The system of claim 46 wherein the cryopump has at least one stage.

81. The system of claim 46 wherein the cryopump has a plurality of stages.